Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 2 (2010) 2801–2804
Procedia Engineering
www.elsevier.com/locate/procedia

8th Conference of the International Sports Engineering Association (ISEA)

Development of a standardized test method for characterizing the stiffness of heel sole segments of sports shoes

Mathew James Dickson, Franz Konstantin Fuss, Michael Burton

School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, PO Box 71, Bundoora 3083, Vic, Australia

Received 31 January 2010; revised 7 March 2010; accepted 21 March 2010

Abstract

Individual suspension of different segments of the heel sole is imperative for optimal 3D cushioning and rear foot control. A test rig was developed which measures the overall structural properties of the heel sole as well as the properties of the medial, lateral, and posterior segments. The structural properties measured are the stiffness as a function of deflection and the influence of viscosity from compression tests of the segments and whole heel. Based on the properties a critique was made of the shoes' supinating effect. This effect is required to counterbalance overpronation in shod running. The level of energy absorption was also assessed. The test method developed does not rely on test persons and is thus more objective than other tests for determining the supinating effect of the shoes.

Keywords: *Adidas Bounce; Mizuno Alchem;, Heel Cushioning;*

1. Introduction

For most athletes, the heel of the shoe comes into contact with the running surface well before full shoe contact. This makes the structure of the heel critical for attenuating any initial shock forces. In the period before foot-flat rotation of the rearfoot occurs about a predominantly sagittal, yet slightly tilted axis. This is referred to as pronation (eversion) and supination (inversion). Shod running with an inappropriate shoe causes overpronation. These critical effects related to the shoe heel give us a natural means of testing the heel. Three segments of the shoe need to be considered. The posterior segment of the heel cushions the initial shock; most runners during a running stride strike their heel on the running surface first. The stiffness of the rear of the heel needs to be high to prevent bottoming out of the heel; this would result in increased shock [1]. The stiffness of the lateral (outer) segment and medial (inner) segment controls the rotation of the rearfoot. To compensate for overpronation and enable supination the lateral side of the heel needs to be less stiff than the medial side.

A number of standards exist around shoe heels. For example ASTM F1976-06 [2] uses an impact test to measure impact attenuation. This standard looks at how the whole heel responds to impact load but does not consider the effect of the various segments on pronation of the foot. Other tests consider the pronation of the foot. For example,

doi:10.1016/j.proeng.2010.04.069

Stiftung Warentest [3] measures the supinating effect of the shoe. This test relies on athletes and so is ultimately not easily reproducible.

To the best of our knowledge, there is no standard so far which considers testing different heel segments. The aim of this study was to test different heel segments of two commercially available running shoes in order to develop a standardized test method for characterizing the stiffness of heel sole segments of sports shoe segments. The energy absorbed in a cycled loading will also be determined.

2. Methods

Testing was conducted using an Instron 5569 with a 50 kN load cell. A 50 mm diameter cylindrical press with a 10 mm radius fillet was used in all of the tests. The press was placed in the upper jaws of the machine and used to press down on the innersole of the shoe at the heel location. A flat anvil restrained the shoe for the full heel test. In the segment tests an anvil was placed under only a portion of the heel. The heel segment, medial, lateral or posterior was selected by rotation of a custom anvil as shown in Figure 1. The land of the anvil is a portion of a 140 mm diameter cylinder offset 10 mm from the centerline. The shoe was attached to the upper press using a small bracket also shown in Figure 1. The shoes were tested by a cycle of two ramp segments (constant crosshead speed) with positive and negative gradients. The two shoes tested are identified in Table 1.

Fig. 1. The shoe testing rig

Table 1. Shoe Details

Shoe ID	Brand	Model	Size	Shoe Tested
Adidas Bounce	Adidas	Ambition PB	11 1/2 UK Men’s	Right
Mizuno	Mizuno	Alchemy	9 UK Men’s	Right

A standard operation procedure was followed for testing on both shoes as shown in Table 2. Each of the release speeds was the same as the compress speed. A rest time of at least a minute was allowed between tests. Data for the tests were sampled at 50 Hz for 500 mm/min, 5 Hz for 50 mm/min and 0.5 Hz for 5 mm/min.

3. Results

3.1. Stiffness

From Figure 2a it is evident that the Adidas shoe has a negative supinating, i.e. an overpronating effect. The Mizuno shoe shows a supinating effect below a compression of approximately 2 mm, above which the heel overpronates. In the whole heel tests (Fig. 2b) both shoes show some degree of foam-like behavior with elastic, collapse and densification phases [4]. This is expected for the Mizuno shoe because it is constructed of foam. For the Adidas shoe this is also the case but with missing foam in the heel. The bounce tube behaves like macro scale cellular solid. The advantage of this is that the deflection (and load) before the collapse point is increased. At collapse energy is absorbed by the heel.

The Adidas shoe is less stiff initially than the Mizuno shoe in the whole heel test. This is mostly due to the sharp increase in stiffness in the rear portion of the Mizuno shoe at a compression of 3 mm. The Mizuno shoe also has less stiffness in the medial and lateral sides.

Table 2. Test list

Test number	Description
1	Full Heel compression to 5kN at 500mm/min and released
2	Repeat
3	Repeat
4	Full Heel compression to 5kN at 50mm/min and released
5	Full Heel compression to 5kN at 5mm/min and released
6	Lateral part compression to 15mm at 500mm/min and released
7	Lateral part compression to 15mm at 50mm/min and released
8	Lateral part compression to 15mm at 5mm/min and released
9	Medial part compression to 15mm at 500mm/min and released
10	Medial part compression to 15mm at 50mm/min and released
11	Medial part compression to 15mm at 5mm/min and released
12	Posterior part compression to 15mm at 500mm/min and released
13	Posterior part compression to 15mm at 50mm/min and released
14	Posterior part compression to 15mm at 5mm/min and released

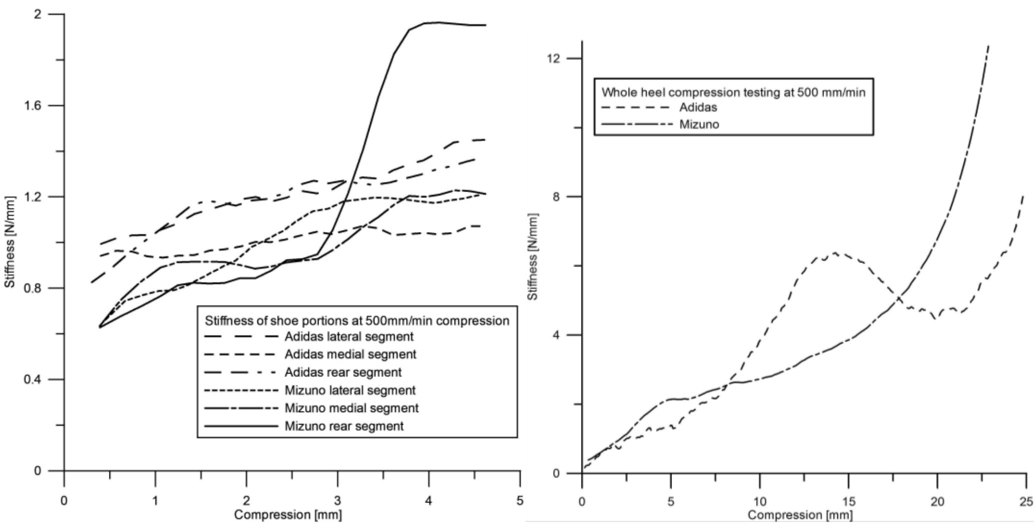

Figure 2. (a) Stiffness of the shoe portions for 500 mm/min crosshead speed; (b) whole heel stiffness at 500 mm/min.

3.2. Energy Absorption

The Mizuno shoe shows better energy absorption than the Adidas one (Table 3) which is due to the foam-based Mizuno sole. There is slightly higher energy absorption on the lateral side of both of the shoes.

Table 3. Energy return (combined data of both crosshead speeds).

Portion	Average energy absorption %	St. Dev. %
Adidas Whole Heel	25.96	1.42
Adidas Lateral Heel	24.61	1.89
Adidas Medial Heel	21.96	1.15
Adidas Posterior Heel	21.93	1.64
Mizuno Whole Heel	32.61	2.22
Mizuno Lateral Heel	36.96	1.98
Mizuno Medial Heel	34.98	0.99
Mizuno Posterior Heel	32.58	1.95

4. Discussion and conclusion

The tests conducted are simple and reproducible for anyone with suitable compression equipment. The test is also suitable for any normal sports shoe and so could form the basis for standardized testing of sports shoes in the future. The measures developed here do not apply to runners whose running style differs significantly from the norm. In particular, those who strike the running surface with foot flat.

Testing showed the importance of conducting multiple full heel compressions to reach a steady state for testing. There was significant variation between the first and third whole heel compression of both shoes. There was little variation between the second and third tests.

Neither of the shoes tested provided significant supinating effect to compensate for pronation of the foot during running. As a cushioning shoe the Mizuno shoe provides better energy absorption in comparison due to foam based sole.

The investigation developed a test method for characterizing the stiffness of sports shoe heel segments. The method was applied to two very different sports shoes. The stiffness of the segments with compression was determined and the energy absorption in a cycled loading found.

References

[1] Shorten MR. The myth of running shoe cushioning. International confrence on the engineering of sport, 2002.
[2] ASTM F1976-06 Standard Test Method for Cushioning Properties of Athletic Shoes Using an Impact Test. ASTM International, West Conshocken USA, 1999.
[3] Stiftung Warentest. Laufschuhe (test for running shoes). Berlin, Germany.
[4] Gibson LJ, Ashby MF. Cellular Solids, Structure and Properties. 2nd Ed. Cambridge University Press, Cambridge, 1997.